Information Circular 80

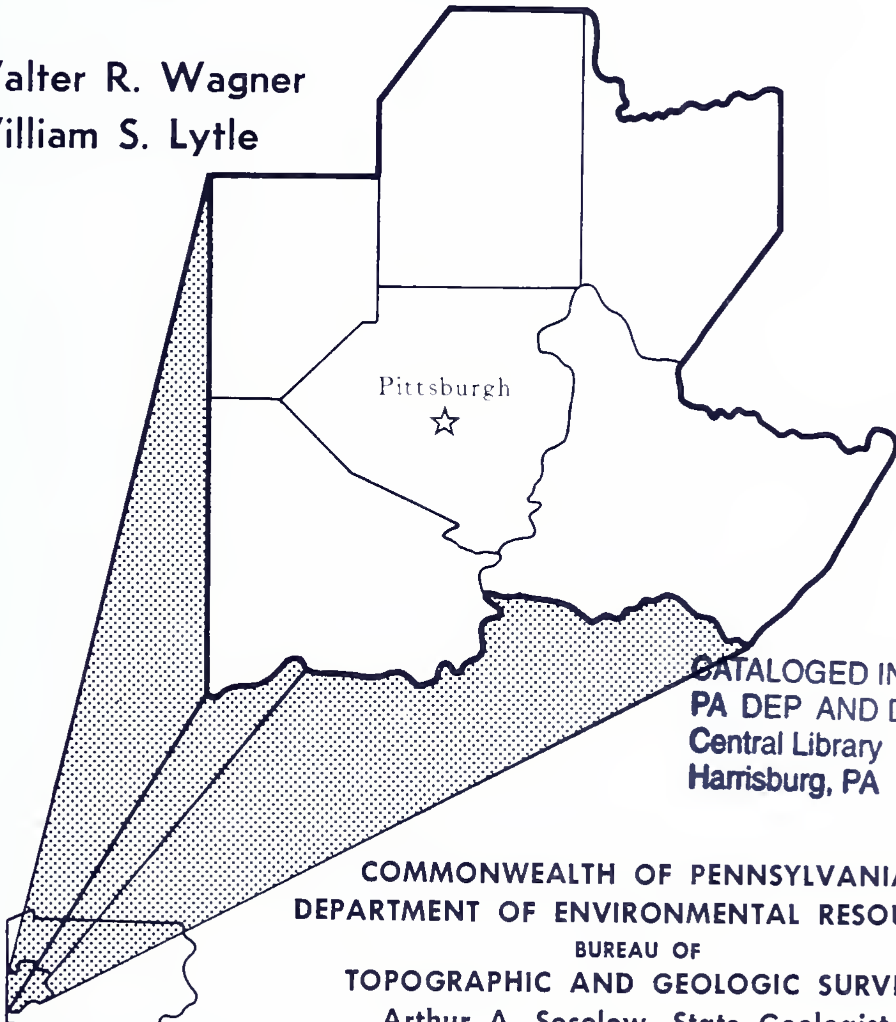
1976

Reprinted 1984

GREATER PITTSBURGH REGION REVISED SURFACE STRUCTURE AND ITS RELATION TO OIL AND GAS FIELDS

Walter R. Wagner

William S. Lytle



COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist
IN COOPERATION WITH
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Information Circular 80

GREATER PITTSBURGH REGION REVISED SURFACE STRUCTURE AND ITS RELATION TO OIL AND GAS FIELDS

by Walter R. Wagner and William S. Lytle

Prepared by the Pennsylvania Geological Survey
in cooperation with the United States
Geological Survey under U.S.G.S. grant 14-08-0001-G-277

PENNSYLVANIA GEOLOGICAL SURVEY
FOURTH SERIES
HARRISBURG

First Printing, 1976
Second Printing, 1984

ISBN: 0-8182-0030-8

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PURCHASED FROM
STATE BOOK STORE, P. O. BOX 1365
HARRISBURG, PENNSYLVANIA 17105

PREFACE

With the completion of the revision of a structure map and an oil and gas fields map of the Greater Pittsburgh Region (Allegheny, Armstrong, Beaver, Butler, Washington, and Westmoreland Counties), Walter R. Wagner of the Oil and Gas Geology Division of the Pennsylvania Geological Survey noticed that many of the gas fields were coincident with the anticlinal axes in this area. Wagner undertook a study of the relationship of the surface structures to the oil and gas fields of the area. He died before completing the text of the report. Using Wagner's detailed notes and nearly completed illustrations, the report was completed by William S. Lytle.

For areas where revised structure maps had not yet been published, updating of the old structure maps was accomplished by using data from 1) the logs of the new oil and gas wells in the area, 2) core hole reports of coal and engineering companies, and 3) outcrop data from strip mining pits, coal mine entries, and quarries. The report describes how these data were used and the relationship of anticlinal and synclinal axes and lines of structural discontinuity to the oil and gas fields and to surface drainage.

This report suggests that detailed surface structures may be used as a clue for exploration for oil and gas. Readers and prospective users of the concepts described here will need to evaluate and test their validity within their own respective operating areas.

The report should be of particular interest to oil and gas operators, professional geologists, planners in the area, mining engineers, and students of the geology of Pennsylvania.

CONTENTS

ILLUSTRATIONS

FIGURES

GREATER PITTSBURGH REGION REVISED SURFACE STRUCTURE AND ITS RELATION TO OIL AND GAS FIELDS

by

Walter R. Wagner

William S. Lytle

ABSTRACT

On completion of the updating of the surface structure map and the oil and gas fields map of the Greater Pittsburgh Region (Allegheny, Armstrong, Beaver, Butler, Washington, and Westmoreland Counties), it was decided to determine whether structure had played any part in the accumulation of oil and gas in the area. The validity of the structural interpretation is supported by its relationship to the surface drainage; the major drainage follows closely the lines of structural discontinuity and the synclinal axes.

The general gas field outline not only conforms to the major structural features, but also, in many specific gas fields, the extensions are along anticlines and the contractions are in synclines, forming specific field outlines. The oil production is located in the broad basins; gas production occurs on the structurally high areas surrounding the basins. Also, a number of the oil fields terminate along the edge of the major structural alignments.

In the early 1900's, geologists indicated that, in this region, structure played an important part in the entrapment of oil and gas. Since then, opinion turned strongly toward stratigraphy as being the main trapping agent. The revised structure maps in this report show that structure plays a significant role in oil and gas accumulation and that many, if not most, of the fields of the Greater Pittsburgh Region may be categorized as combined traps. Because surface structures conform so well to subsurface oil and gas fields, detailed surface structures may be used as a clue for exploration.

INTRODUCTION

In February 1973, the Pennsylvania Geological Survey, in cooperation with the U. S. Geological Survey, began preparation of a series of maps of the Greater Pittsburgh Region, which covers Allegheny County, where Pittsburgh is located, and the five surrounding counties of Beaver, Butler, Armstrong, Westmoreland, and Washington (Figure 1). The maps included a surface structure map (Wagner, Heyman, and others, 1975), a geologic map (Wagner, Craft, and others, 1975), a map showing thick-

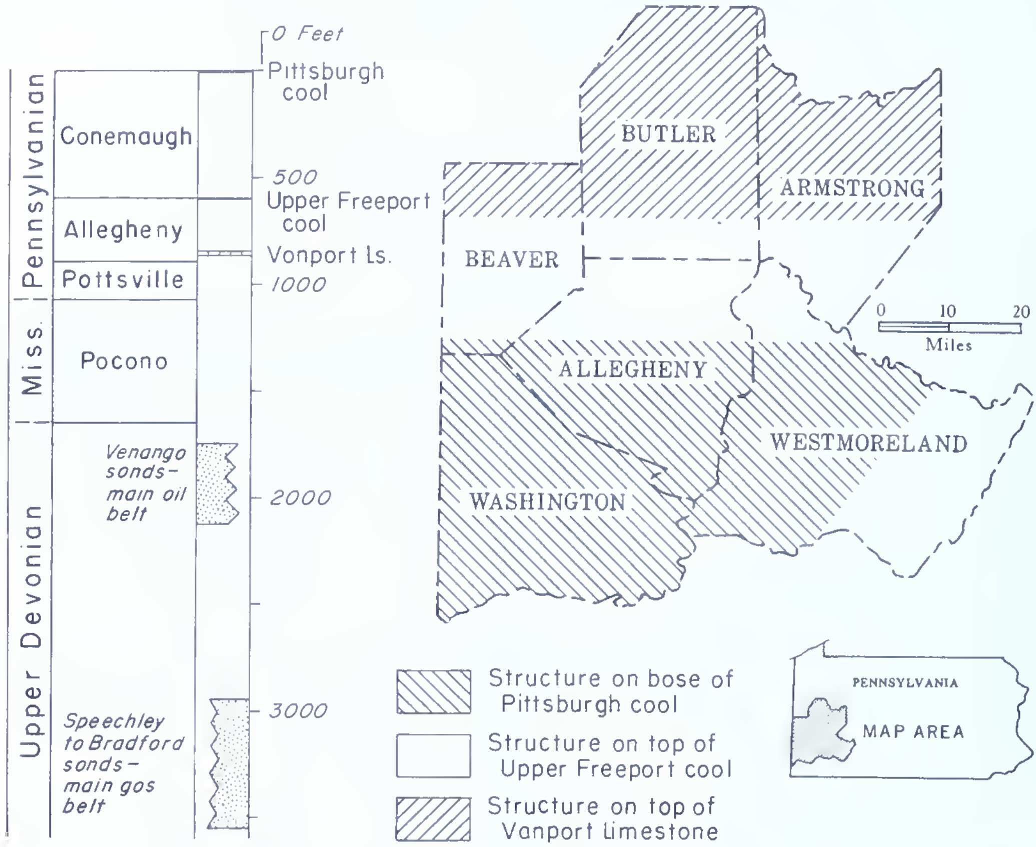


Figure 1. Location map of Greater Pittsburgh Region, showing units on which structure maps were drawn. Column at left shows the stratigraphic relationship of these units to the oil- and gas-producing zones.

ness of rock to the Pittsburgh coal (Cortis and others, 1975), and an oil and gas fields map (Lytle and Balogh, 1975). The present report discusses the surface structure map and its relevance to the oil and gas fields map.

Structure maps of parts of the Greater Pittsburgh Region have been available for many years from U. S. Geological Survey folios and bulletins and from Pennsylvania Geological Survey atlases. Most of these maps were published at a scale of 1:62,500 (one inch equals approximately one mile) to correspond to the 15-minute topographic quadrangle series. Since then, the 15-minute series has been replaced by the more detailed 7½-minute quadrangles (scale 1:24,000), which permit more precise location of outcrops and also more precise determination of elevations of units upon which structure is drawn. In addition, and perhaps more significantly, a large amount of subsurface data have been collected through the years by the Pennsylvania Geological Survey; these data aid in revising structure maps, particularly in areas where the structural unit is deep below the

surface. Subsurface data are also of considerable value in resolving conflicting structural interpretations. Thus, subsurface information and more detailed topographic maps necessitate revision of many structure maps, not only in the Greater Pittsburgh Region, but over most of western Pennsylvania.

PREPARATION OF THE STRUCTURE MAP

All four maps, the structure map, geologic map, Pittsburgh coal overburden map, and oil and gas fields map, are published at a scale of 1:125,000 (one inch equals approximately two miles). The base for each map is the Greater Pittsburgh Region map (U. S. Geological Survey, 1971), which essentially is a reduction of the 7½-minute topographic quadrangles and has a contour interval of 100 feet. Because the first three maps are intimately connected, it was necessary that they conform to each other and to the topographic base. Therefore, the structure map was prepared first, and the geologic map and overburden map were produced from the structure map.

The structure map was made according to the following procedure:

1. Published structure maps were compiled at a scale of 1:62,500, and revisions were made based on elevations of coal from deep mine maps.
2. The 1:62,500 compilation was enlarged on transparent film to 1:24,000 and overlaid on 7½-minute topographic quadrangles.
3. Elevations of surface data were located on the overlay using the outcrop of the structural unit as obtained from published geologic maps and from locations on the 7½-minute quadrangle of strip mining pits, coal mine entries, and quarries.
4. Elevations of subsurface data were plotted on the overlay. Most of these figures were calculated from oil and gas well records and from core hole reports of coal and engineering companies.
5. Combining the existing structure and the new control points, a new map was re-contoured on 20-foot intervals, except in eastern Westmoreland County where the interval was increased to 50 and 100 feet. As a result, the structure has been largely revised in Beaver, Butler, Armstrong, and part of Westmoreland Counties and slightly revised in Allegheny and northern Washington Counties; it remains unchanged in southern Washington County, where recent structural and geologic mapping has been done by Berryhill (1964), Berryhill and Swanson (1964), Berryhill and Schweinfurth (1964), Swanson and Berryhill (1964), Kent (1967, 1969, 1972), Schweinfurth (1967), and Roen (1968, 1970, 1973).

6. The new structure map was placed over the 7½-minute topographic quadrangle, and another transparency was placed over the structure map. Upon the new transparency the geologic contacts were delineated, determined by the underlying structural and topographic contours. Where the new geologic map differed significantly from the published geologic maps, the new structure map was checked for errors and corrected if necessary.
7. All of the structure maps, one corresponding to each 7½-minute topographic quadrangle, were inked, photographically reduced to 1:125,000, assembled, and scribed on the base map of the Greater Pittsburgh Region (U. S. Geological Survey, 1971).

The structure map is drawn on three units: the base of the Pittsburgh coal, the top of the Upper Freeport coal, and the top of the Vanport Limestone. The stratigraphic relationship of these units to each other and to the oil- and gas-producing zones below is indicated on the columnar section in Figure 1.

Figure 2 shows the major anticlinal and synclinal axes of the Greater Pittsburgh Region. Lines of structural discontinuity, as used in this paper, represent narrow zones or trends along which fold axes terminate, diminish, or change direction. These lines of structural discontinuity, particularly the southern one and the two through Butler and Armstrong Counties, appear to influence the distribution of the oil fields. The line of structural discontinuity in Washington County defines the southern border of the McDonald oil field; in Butler County the southern line of structural discontinuity "truncates" the Little Creek and Renfrew-McCalmont fields; and the northern line of structural discontinuity terminates the Bullion-Clintonville and Cherry Valley oil fields.

REVISED STRUCTURE IN ARMSTRONG COUNTY

The comparison between structure taken from the preliminary map of Edmunds (1974a) and the revised structure is shown in Figure 3. Both maps are simplified in that they show 100-foot contours only, whereas the original maps have a 20-foot contour interval. The northern part of the maps is contoured on top of the Vanport Limestone, and the southern part shows structure on top of the Upper Freeport coal. The two maps are similar in that the main folds remain in the same places, but the main folds are more discontinuous in the revised structure, and subsidiary folds occur between the main folds. Therefore, Figure 3A is a more generalized version of Figure 3B. Structure can also be shown by the use of fold axes (Figure 4), which, in the revised structure map, are greater in number.

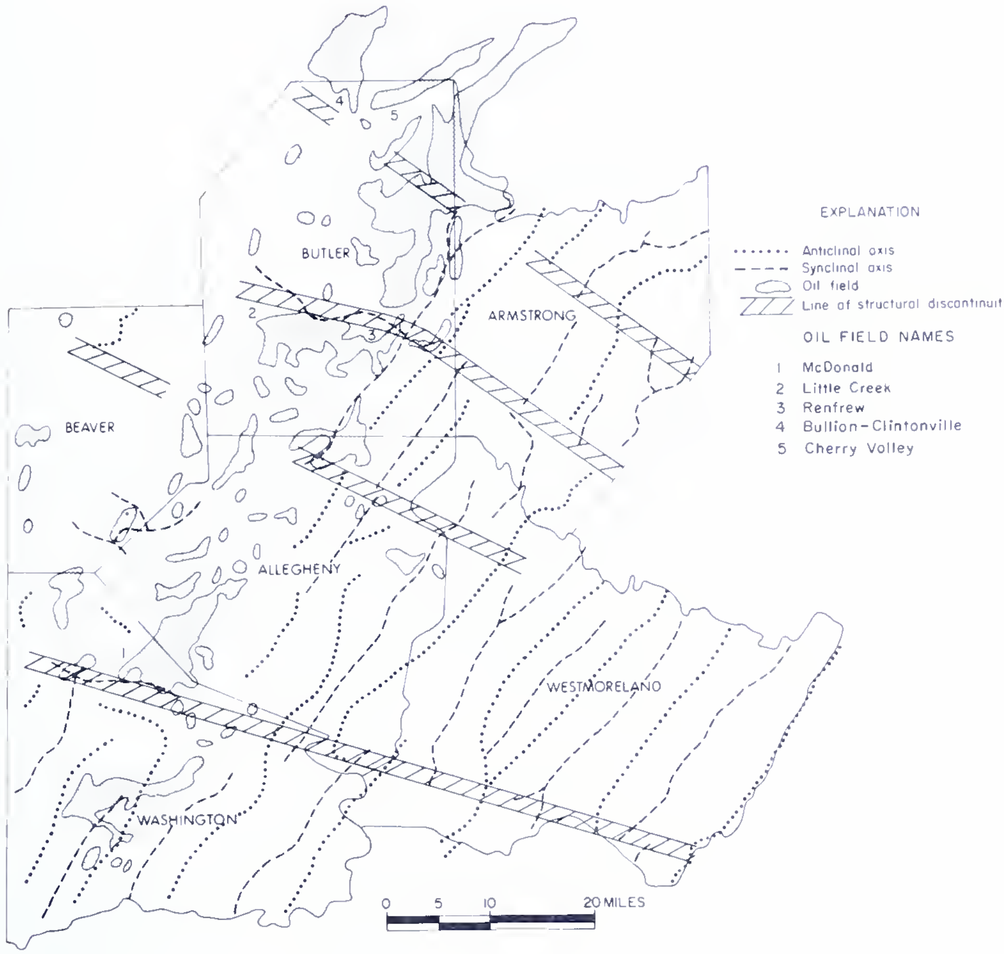


Figure 2. The relationship of the major structures and lines of structural discontinuity to the oil fields in the Greater Pittsburgh Region.

The validity of this structural interpretation is supported by its relationship to surface drainage and also to the Upper Devonian oil and gas fields that occur approximately 1,500 feet below. The following relationships can be observed with respect to the surface drainage. Crooked Creek lies within the southern line of structural discontinuity (Figures 2 and 4), as does the meander of the Allegheny River and of Buffalo Creek. Cowanshannock Creek tends to follow the northern line of structural discontinuity at a slight angle.

Mahoning Creek remains in the syncline, and where it climbs the anticline, the meanders appear to be controlled by the local folds. The main meanders, on Redbank Creek and the Allegheny River at the northern boundary and on the Kiskiminetas River at the southern

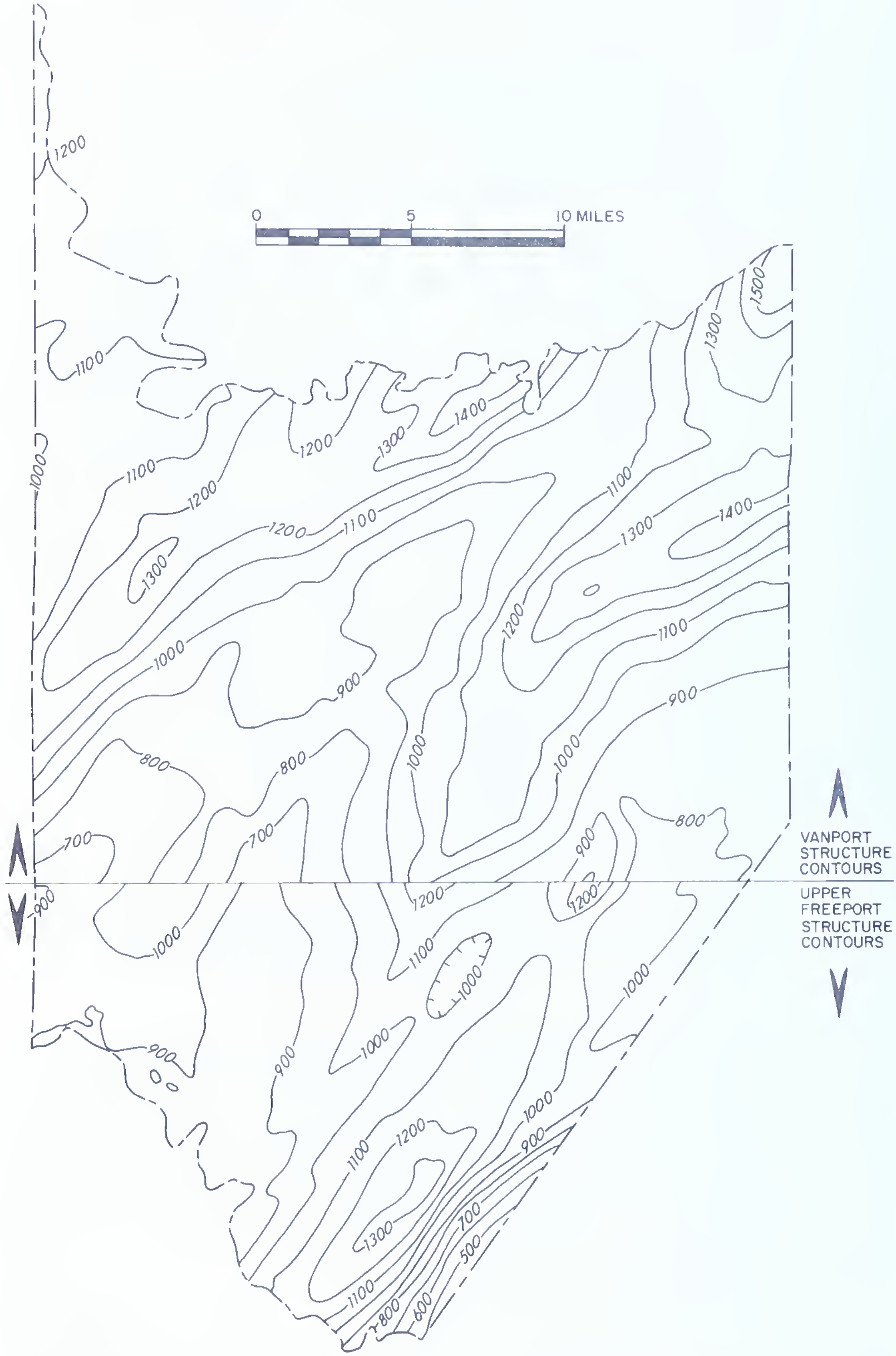


Figure 3A. Preliminary structure map of Armstrong County (from Edmunds, 1974a). Contour interval 100 feet.

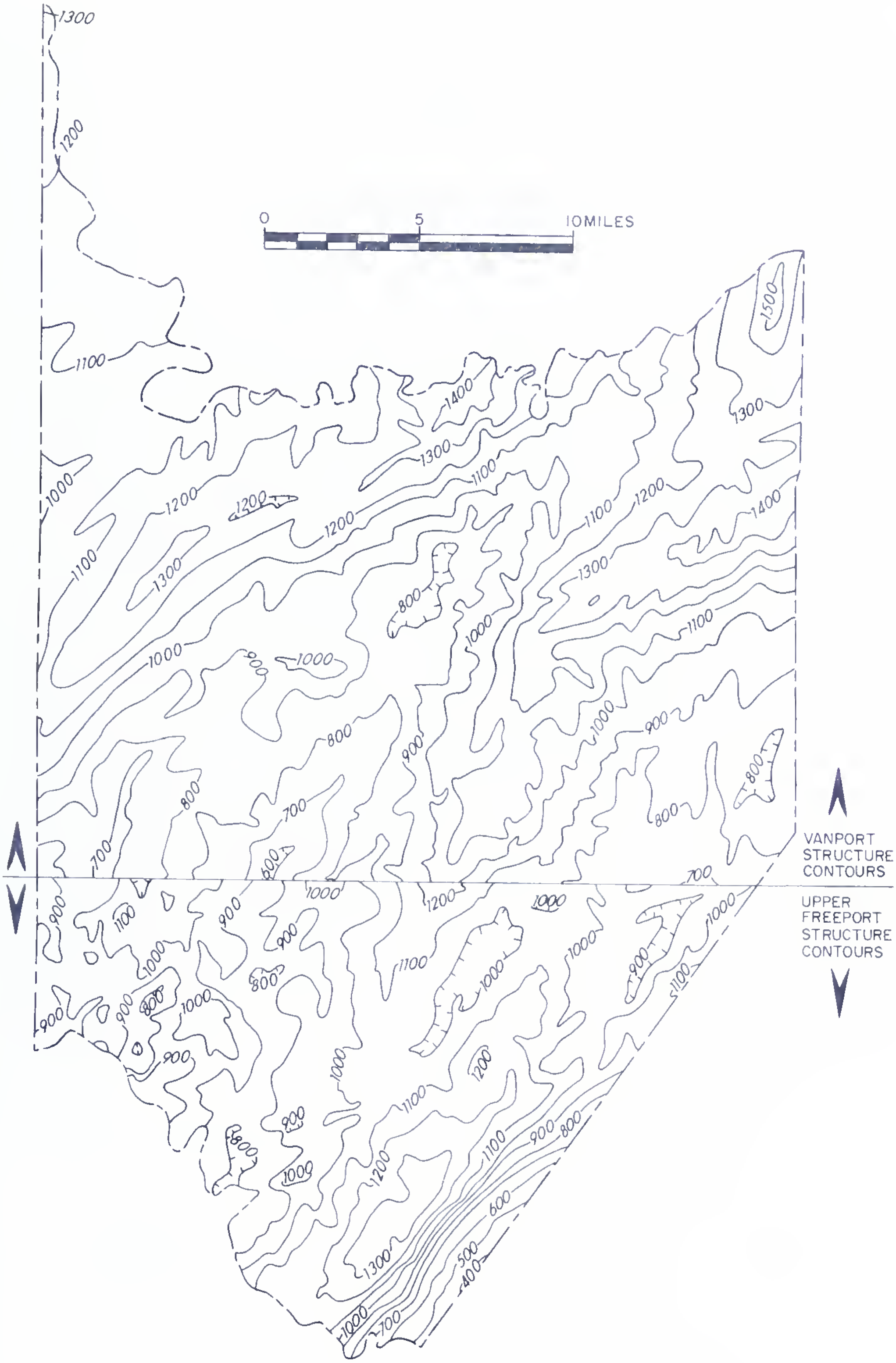


Figure 3B. Revised structure map of Armstrong County. Contour interval 100 feet.

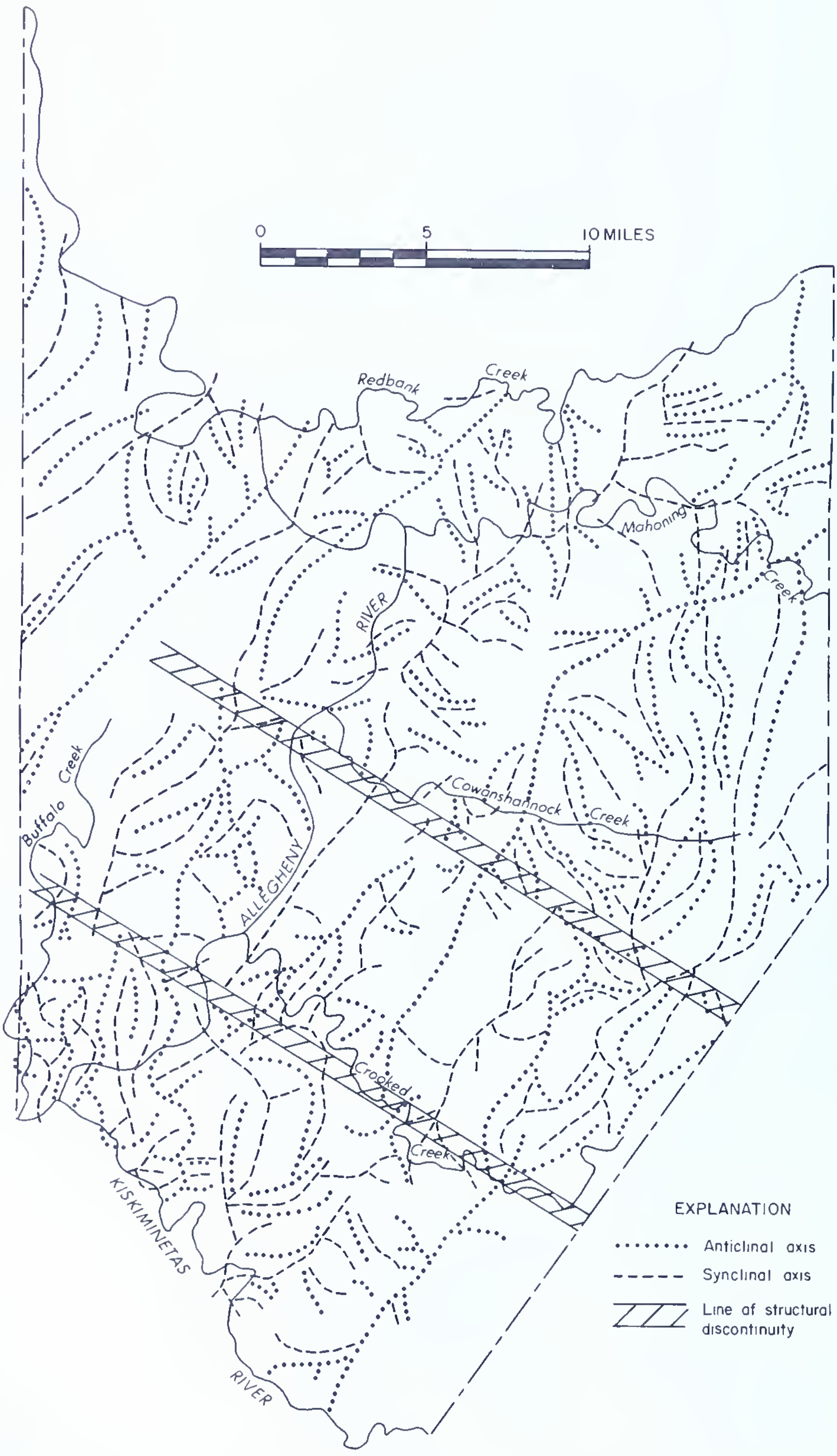


Figure 4. Fold axes of revised structure map and major stream drainage in Armstrong County.

boundary, occur along synclinal axes. The Allegheny River from Mahoning Creek south through the southern line of structural discontinuity remains in a syncline, but at the northern line of structural discontinuity, it crosses an anticline. Where the Allegheny River cuts across two anticlines in southwestern Armstrong County, it does so at the low points of the plunge. The Allegheny River appears more affected by the structure than do most of its tributary streams.

The oil and gas fields outline (Figure 5) is taken from the map by Lytle and Balogh (1975), which is based on Map 22 (oil and gas well base map) of the Pennsylvania Geological Survey. The map does not indicate the boundaries of individual producing sands, but combines all of the producing sands, thus giving a general outline of production.

Therefore, in Armstrong County, not only does the general gas field outline conform to major structural features, but also, in many specific gas fields the extensions are along anticlines and the contractions are in synclines, forming specific field outlines.

Figure 5 shows the fold axes superimposed on the oil and gas fields of Armstrong County. The three major anticlines, starting in the northwest, are the Kellersburg, Greendale-Sabinsville, and Murrysville. All of these folds are underlain by broad linear areas of gas production. The wide synclinal zone between the Kellersburg and Greendale-Sabinsville anticlines contains minor folds, and production there is intermittent; the minor synclinal axes tend to be nonproductive. Within the synclinal area the amoeboid-like boundaries of the producing fields in many instances conform to the minor fold axes, the lobes extending along anticlinal axes and retreating along synclinal axes.

The fold axes do not form a perfect fit with the limits of the oil and gas fields for several reasons: 1) The validity of the structure map is dependent on the number of control points. In areas of relatively few control points, the structure will be less valid than in areas of dense control. 2) The oil and gas fields lie approximately 900 to 3,000 feet below the datum of the structure map. Thus, the correlation would not be expected to be as good as it would be if the map were on a datum that contained the oil and gas.

REVISED STRUCTURE IN BUTLER COUNTY

Figure 6 compares the preliminary structure map of Butler County (Edmunds, 1974b) with the revised structure. The northern 75 percent of each map is contoured on the top of the Vanport Limestone, whereas the southern 25 percent is on the top of the Upper Freeport coal. Both maps show the same regional structure from northwest to southeast: a

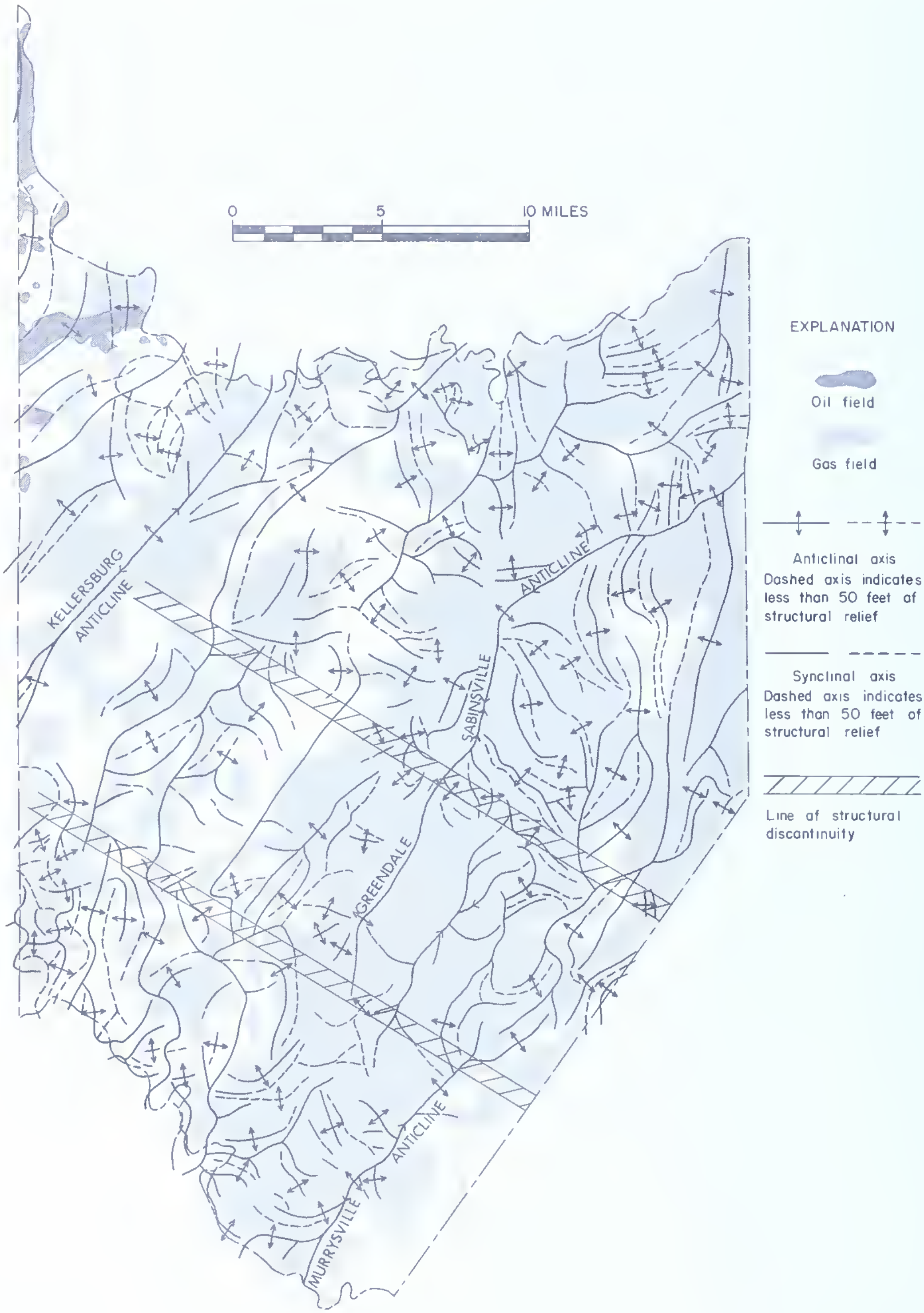


Figure 5. Fold axes of revised structure map and oil and gas fields of Armstrong County.

Figure 6A. Preliminary structure map of Butler County (from Edmunds, 1974b). Contour interval 100 feet.

gentle south dip, a steeper dip, a large basin covering much of the southern half of Butler County, and the Kellersburg anticline at the southeast corner. The main difference between the two maps is the addition on the revised map of minor folds within the regional setting.

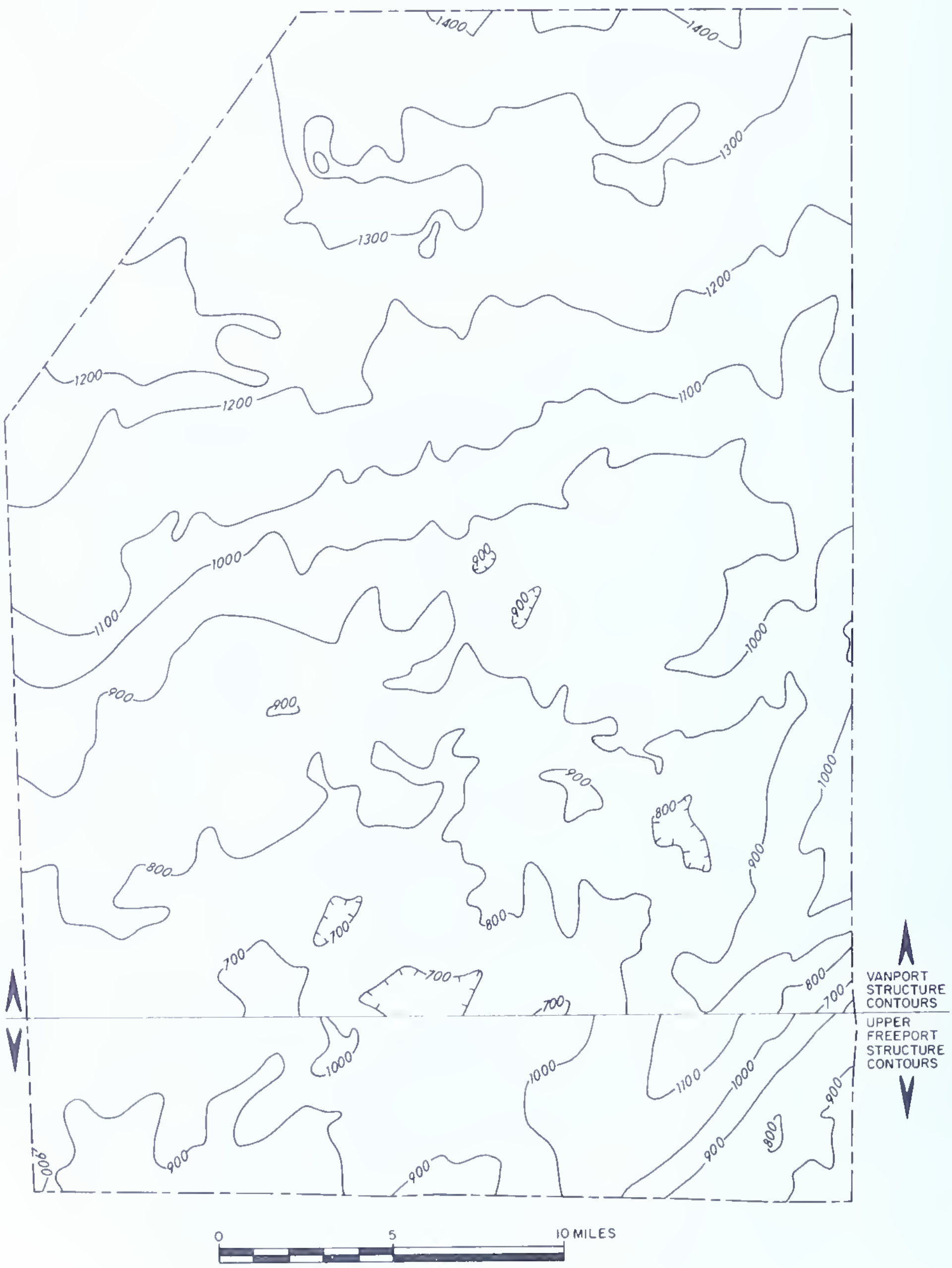


Figure 6B. Revised structure map of Butler County. Contour interval 100 feet.

Figure 7 is a revised structure map of Butler County overlaid on the oil and gas fields map. Oil production is located in the broad basin in the southern part of the county and becomes concentrated as the basin narrows and trends to the northeast, leaving the county in the northeast

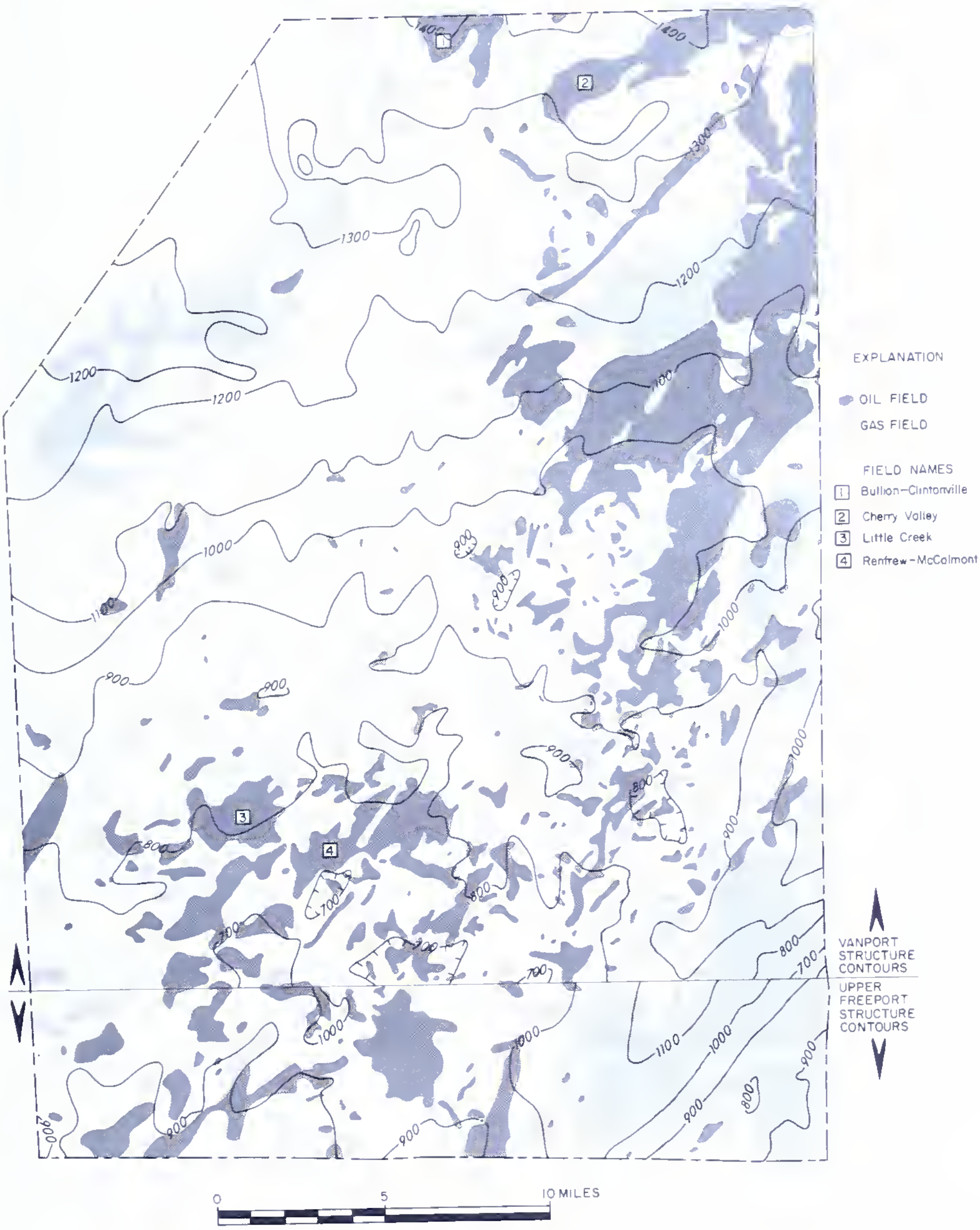


Figure 7. Revised structure and oil and gas fields of Butler County. Contour interval 100 feet.

corner. Gas is localized on the structurally high areas northwest and southeast of the basin.

Most of the oil within the structural basin comes from the lower 75 to 100 feet of the Venango Group of sands (Lytle and Heeren, 1955). The

Venango Group is about 300 feet thick and lies about 1,000 feet below the Vanport Limestone. The lower one third of the Group contains the Venango Third, Venango Third Stray, and equivalent sands. Assuming that a relationship exists between oil production and the structural basin, then either the structure determined the location of these sands within the basin, or, if the sands are more widespread, as they probably are, the basin was formed after deposition of the sands and before the accumulation of the oil.

More specific relationships between surface structure axes and the oil and gas fields are shown in Figure 8. A major line of structural discontinuity extends west-northwest through south-central Butler County (Figure 4) and meets the line of structural discontinuity that Crooked Creek follows in Armstrong County. The line of structural discontinuity is represented by a west-northwest-trending synclinal axis and the termination of most of the oil fields along the southern edge of the line. Along the eastern edge of the oil fields where they extend across the line of structural discontinuity, oil production is from different sands: Venango Third south of the line and Knox Fourth north of it (Lytle and Heeren, 1955).

Another less obvious line of structural discontinuity extends northwest-southeast through northern Butler County and is indicated by the lack of structural axes crossing it and the ending of the Bullion-Clintonville and Cherry Valley oil fields which extend northeast into Venango County.

In the eastern half of the county there is a strong relationship between surface structure and limits of the oil and gas fields. In east-central Butler County, the synclinal axes coincide very well with the nonproductive areas within the main oil field belt. South of the major line of structural discontinuity that cuts across central Butler County is a group of gas fields that underlies a structural dome of the Vanport Limestone.

In western Butler County, the structural axes decrease in amplitude so that many of the folds have less than 50 feet of structural relief, and the axes are also much more irregular in trend. As a consequence, some of the indicated structure may be caused by stratigraphic changes such as thinning or disappearance of the Vanport Limestone or thickening and thinning of sandstone units below the Vanport.

An example of the latter case occurs in northwestern Butler County, where two synclinal axes are shown on Figure 8, labelled A and B. "A" trends northeast-southwest and is parallel to and just southeast of the county border. "B" is at right angles to "A" and extends through the gas field that produces from the Berea and/or Murrysville sands 900 feet below the Vanport. Figure 9 shows the thickness of the Homewood Sandstone, which lies 50 feet below the Vanport in this area. The Homewood

Figure 8. Fold axes of the revised structure map and oil and gas fields of Butler County.

is thin or absent exactly where the synclines occur in the Vanport Limestone. These "synclines" probably disappear below the Homewood Sandstone. Thus, the gas field is not affected by the syncline in the Vanport, and the structural high probably has a northeast trend which coincides with the gas field.

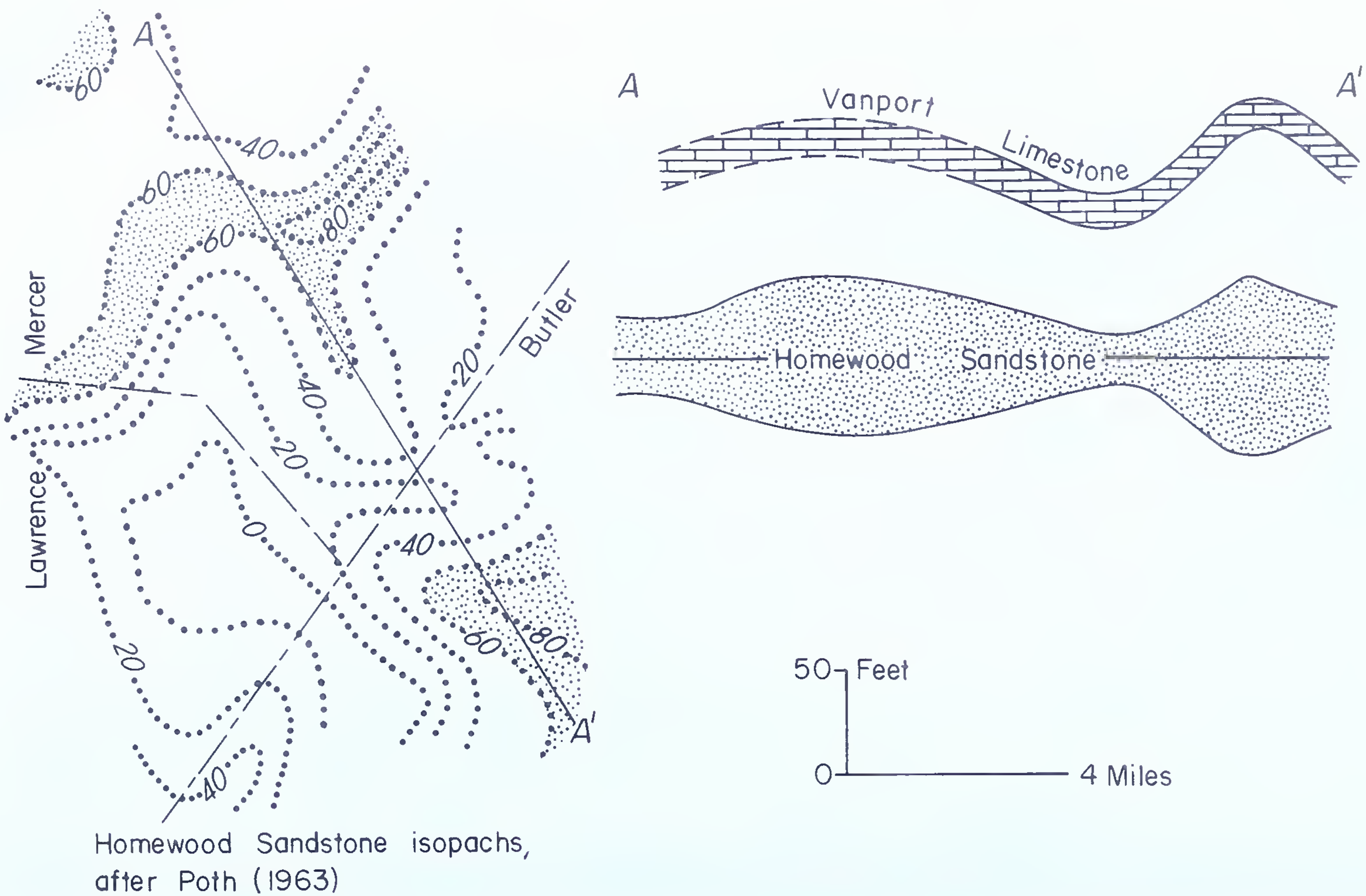


Figure 9. Vanport datum affected by facies change in underlying sandstone unit, giving false structural picture in areas of low structural relief.

REVISED STRUCTURE OF WASHINGTON COUNTY

Figure 10 illustrates the structure on the base of the Pittsburgh coal seam overlaid on the oil and gas fields of Washington County. Much of this structure is taken from the recent U. S. Geological Survey Geologic Quadrangle (GQ) Maps (Berryhill, 1964; Berryhill and Schweinfurth, 1964; Berryhill and Swanson, 1964; Swanson and Berryhill, 1964; Kent, 1967, 1969, 1972; Schweinfurth, 1967; and Roen, 1968, 1970, 1973), which cover large portions of the county at 1:24,000 scale. The general relationship of the structure to gas on the Washington anticline and the Westland

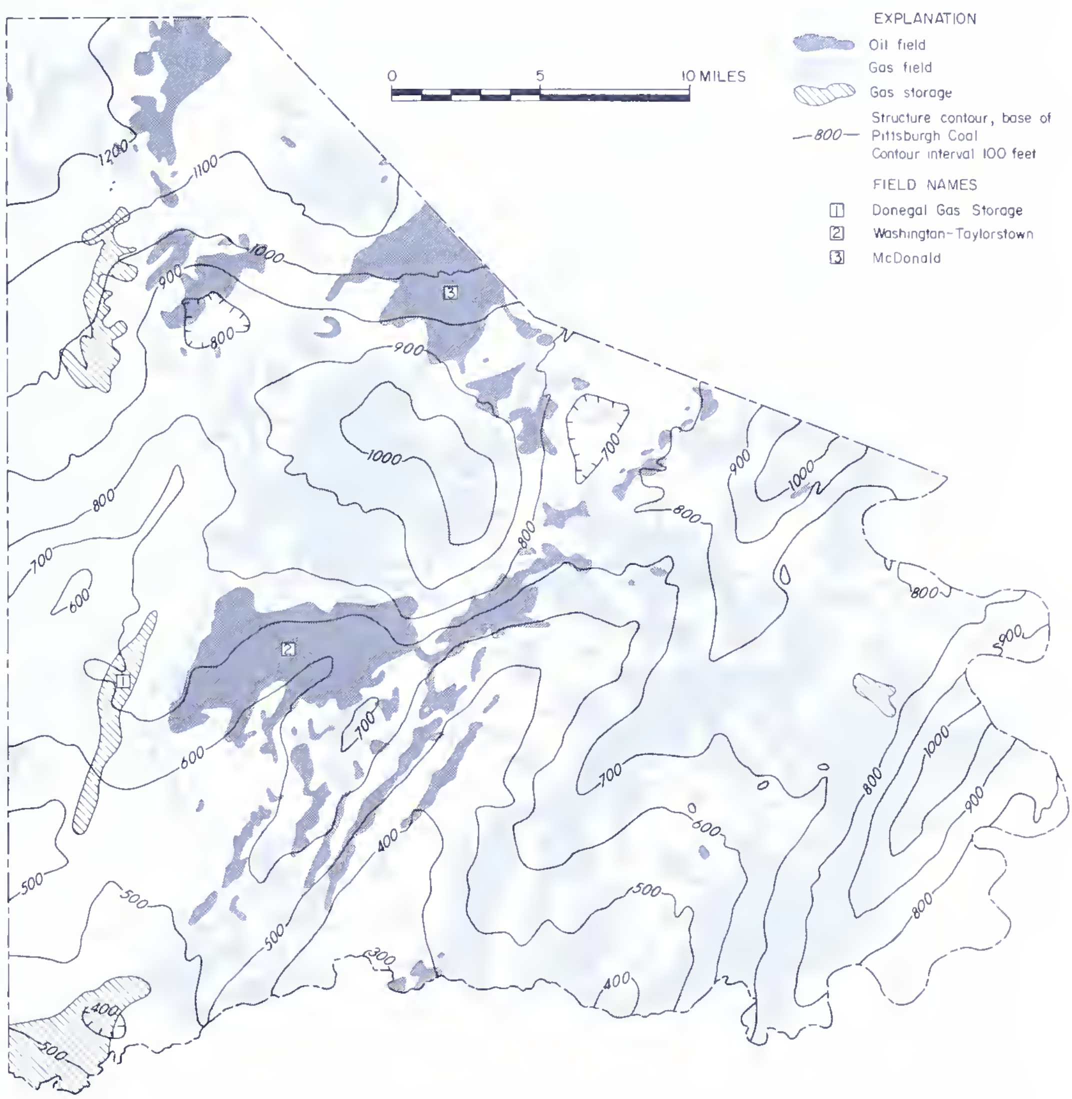


Figure 10. Washington County oil and gas fields and structure contours on the base of the Pittsburgh coal. Contour interval 100 feet.

dome is obvious, as is the relative lack of production in the Nineveh syncline. More specific relationships are shown on the structural axes overlay (Figure 11), where: 1) In the northwestern corner of the county the curving anticlinal axis conforms to the curve of the gas field. 2) Gas production occurs below the culmination of the Candor dome. 3) The Donegal gas storage field underlies a spur of the Claysville anticline. 4) Nonproduction is shown by the indentation of the Washington-Taylorstown oil field along the axis of the Finney syncline.

The northwest-southeast line of structural discontinuity (Figures 2 and 11) through Washington County is recognized in the eastern part of

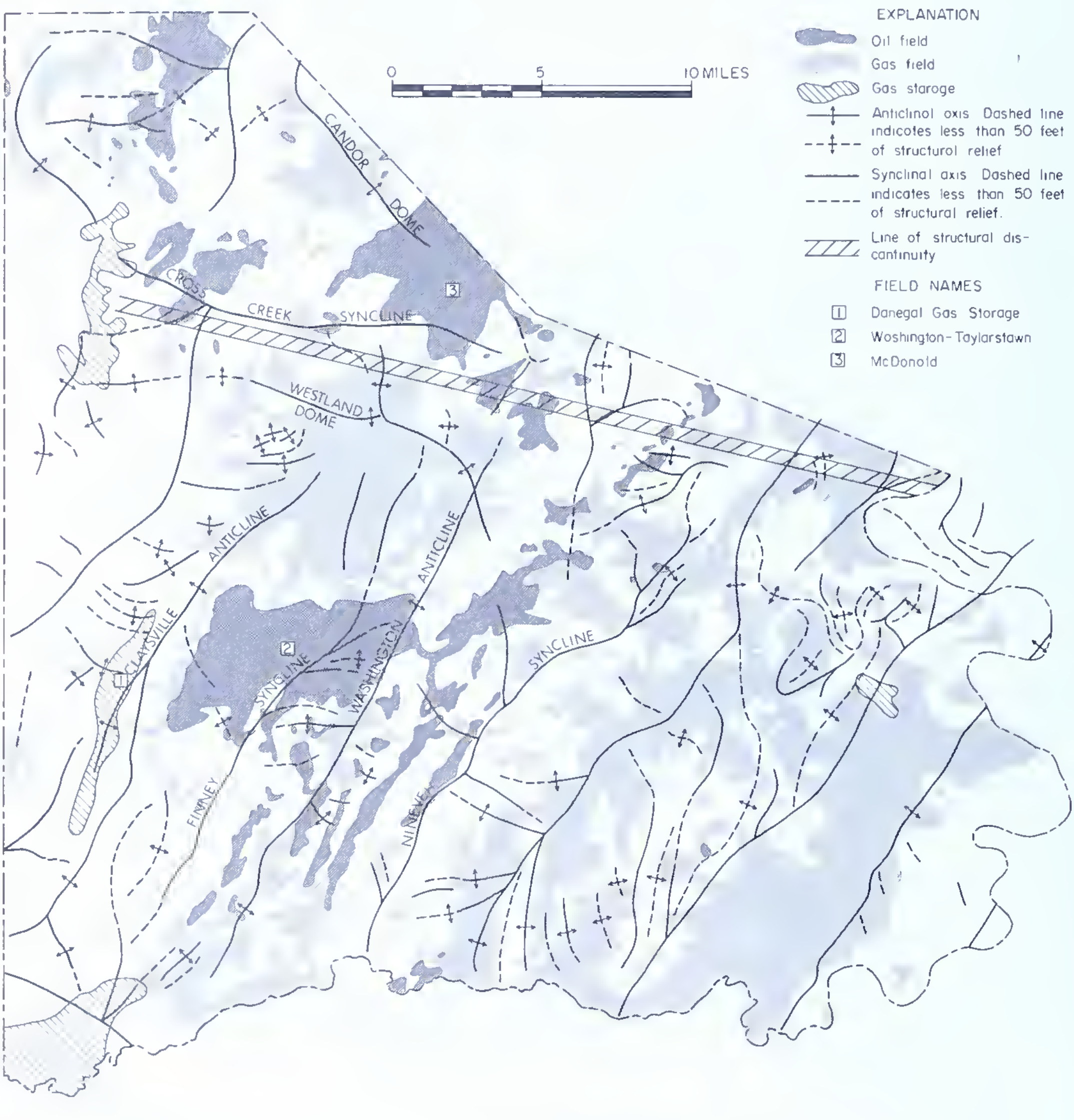


Figure 11. Washington County oil and gas fields and structural axes on the Pittsburgh coal.

the county by the plunging and bending of the structural axes. In the western part of the county, the line of structural discontinuity follows the Cross Creek syncline. Along this line, gas fields are fewer than on either side of the zone, and the McDonald oil field is bounded by the line.

CONCLUSIONS

Many of the structure maps published prior to the Greater Pittsburgh Regional Studies are generalized in that they do not show the irregularities of the structure. In the revised structure maps, the irregularities are delineated; they indicate that the major fold trends are more discontinuous, and their discontinuities commonly are aligned in a northwest-southeast zone. In addition, the irregularities of structure define numerous minor folds present between the major folds. These minor folds commonly appear to be responsible for the heretofore seemingly arbitrary boundaries of oil, and particularly gas, fields.

In the early 1900's, Butts (1906) and Griswold and Munn (1907) indicated that structure in this region played an important part in entrapment of oil and gas. Since then, opinion has turned strongly toward stratigraphy as being the main trapping agent (Fettke, 1938; McGlade, 1967). The revised structure map definitely shows that structure plays a significant role in oil and gas accumulation, and that many, if not most, of the fields of the Greater Pittsburgh Region may be categorized as combined traps.

Because surface structures conform so well to subsurface oil and gas fields, detailed surface structures may be used as a clue for exploration in areas of recent drilling such as Cambria, Somerset, eastern Westmoreland, and eastern Indiana Counties. In these counties, detailed structure maps can be made using a coal, such as the Lower Kittanning of the Allegheny Group, as a reference marker, if core hole data can be obtained from the coal operators.

Preparation of the maps takes a minimal amount of time, once the data have been accumulated. It is estimated that the revision of the structure map entailed four days per 7½-minute quadrangle.

REFERENCES

Berryhill, H. L. (1964), *Geology of the Amity quadrangle, Pennsylvania,* U. S. Geol. Survey Geol. Quad. Map GQ 296.

Berryhill, H. L. and Schweinfurth, S. P. (1964), *Geology of the Ellsworth quadrangle, Pennsylvania,* U. S. Geol. Survey Geol. Quad. Map GQ 333.

Berryhill, H. L. and Swanson, V. E. (1964), *Geology of the Washington West quadrangle, Pennsylvania,* U. S. Geol. Survey Geol. Quad. Map GQ 283.

Butts, Charles (1906), *Economic geology of the Kittanning and Rural Valley quadrangles, Pennsylvania,* U. S. Geol. Survey Bull. 279.

Cortis, S. E., Alexander, T. B., Edmunds, W. E., and Craft, J. L. (1975), *Greater Pittsburgh Region maps of mined-out areas and thickness of rock over the Pittsburgh coal,* Pa. Geol. Survey, 4th ser., Map 45.

Edmunds, W. E. (1974a), *Preliminary structure contour map of Armstrong County, Pennsylvania,* Pa. Geol. Survey, 4th ser., open-file rept.

——— (1974b), *Preliminary structure contour map of Butler County, Pennsylvania,* Pa. Geol. Survey, 4th ser., open-file rept.

Fettke, C. R. (1938), *The Bradford oil field, Pennsylvania and New York,* Pa. Geol. Survey, 4th ser., Min. Resource Rept. 21.

Griswold, W. T. and Munn, M. J. (1907), *Geology of oil and gas fields in Steubenville, Burgettstown, and Claysville quadrangles, Ohio, West Virginia, and Pennsylvania,* U. S. Geol. Survey Bull. 318.

Kent, B. H. (1967), *Geologic map of the Hackett quadrangle, Pennsylvania,* U. S. Geol. Survey Geol. Quad. Map GQ 630.

——— (1969), *Geologic map of the Mather quadrangle, southwestern Pennsylvania,* U. S. Geol. Survey Geol. Quad. Map GQ 826.

——— (1972), *Geologic map of the Prosperity quadrangle, southwestern Pennsylvania,* U. S. Geol. Survey Geol. Quad. Map GQ 1003.

Lytle, W. S. and Heeren, L. A. (1955), *Oil and gas field atlas of the Butler quadrangle,* Pa. Geol. Survey, 4th ser., Spec. Bull. 7.

Lytle, W. S. and Balogh, L. J. (1975), *Greater Pittsburgh Region oil and gas fields map,* Pa. Geol. Survey, 4th ser., Map 44.

McGlade, W. G. (1967), *Oil and gas geology of the Amity and Claysville quadrangles, Pennsylvania,* Pa. Geol. Survey, 4th ser., Min. Resource Rept. 54.

Pennsylvania Geological Survey (1974), *Oil and gas well base map of Kittanning, Rural Valley, Freeport, and Elders Ridge quadrangles,* Pa. Geol. Survey, 4th ser., Map 22.

Poth, C. W. (1963), *Geology and hydrology of the Mercer quadrangle, Mercer, Lawrence, and Butler Counties, Pennsylvania,* Pa. Geol. Survey, 4th ser., Water Resource Rept. 16.

Roen, J. B. (1968), *Geologic map of the Monongahela quadrangle, southwestern Pennsylvania,* U. S. Geol. Survey Geol. Quad Map GQ 743.

——— (1970), *Geologic map of the Waynesburg quadrangle, southwestern Pennsylvania,* U. S. Geol. Survey Geol. Quad. Map GQ 838.

——— (1973), *Geologic map of the Midway quadrangle, Washington County, southwestern Pennsylvania,* U. S. Geol. Survey Geol. Quad. Map GQ 1067.

Schweinfurth, S. P. (1967), *Geologic map of the California quadrangle, Pennsylvania,* U. S. Geol. Survey Geol. Quad. Map GQ 648.

Swanson, V. E. and Berryhill, H. L. (1964), *Geology of the Washington East quadrangle, Pennsylvania,* U. S. Geol. Survey Geol. Quad. Map GQ 334.

U. S. Geological Survey (1971), *Greater Pittsburgh Region, Pennsylvania, topographic map.*

Wagner, W. R., Craft, J. L., Heyman, Louis, and Harper, J. A. (1975), *Greater Pittsburgh Region geologic map and cross sections,* Pa Geol. Survey, 4th ser., Map 42.

Wagner, W. R., Heyman, Louis, Craft, J. L., Edmunds, W. E., and Harper, J. A. (1975), *Greater Pittsburgh Region structure contour map,* Pa. Geol. Survey, 4th ser., Map 43.

ISBN: 0-8182-0030-8